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CHEMICAL ABSTRACTS, vol. 93, no. 3, 21st July 1980, page 738, abstract no. 26739t, Columbus, Ohio, US; R.D. ALLAN et al.: "Synthesis of analogs of GABA. III. All four stereoisomers of 3-aminocyclopentanecaroxylic acid and a stereochemical correlation with amidinomycin"

(73) Proprietor: **Chiroscience Limited**
Science Park
Milton
Cambridge CB4 4WE (GB)

(72) Inventor: **Evans, Christopher Thomas**
Stable Cottage,
Fowlmere Road
Heydon,
Hertfordshire SG8 8PU (GB)
Inventor: **Roberts, Stanley Michael**
Combe Cottage,
Slittercombe Lane
Kenton,
Devon EX6 8NH (GB)

(74) Representative: **Perry, Robert Edward et al**
GILL JENNINGS & EVERY
Broadgate House
7 Eldon Street
London EC2M 7LH (GB)

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CHEMICAL ABSTRACTS, vol. 91, no. 25, 17th December 1979, page 25, abstract no. 204205j, Columbus, Ohio, US; G.A.R. JOHNSTON et al.: "Stereospecific actions of GABA analogs"

TETRAHEDRON LETTERS, vol. 28, no. 17, July 1987, pages 1887-1888, Oxford, GB; S. SICSIC et al.: "Chemoenzymatic approach to carbocyclic analogues of ribonucleosides and nicotinamide ribose"

EUROPEAN JOURNAL OF MEDICINAL CHEMISTRY, vol. 24, no. 4, July-August 1989, pages 415-420, Paris, FR; M. IKBAL et al.: "Synthèse des deux énantiomères de l'analogue carbocyclique du nicotinamide ribose et évaluation de leurs propriétés biologiques"

JOURNAL OF ORGANIC CHEMISTRY, vol. 43, no. 12, 9th June 1978, pages 2311-2320, American Chemical Society, Washington DC, US; S. DALUGE et al.: "Synthesis of carbocyclic aminonuleosides"

Heterocycles, vol. 27, no. 12, 1988, pages 2839-2841

Description

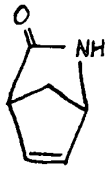
Field of the Invention

This invention relates to chiral compounds having utility as intermediates in the synthesis of anti-viral agents, and to a process for their preparation.

Background of the Invention

Various 9-substituted purines are known as anti-viral and anti-neoplastic agents. One such compound, known as AZT, has been used for the treatment of AIDS. More recent examples are disclosed in EP-A-4268672, US-A-4742064, and also in GB-A-2217320 which, by way of specific illustration, describes a compound known as Carbovir (carbocyclic 2',3'-didehydro-2',3'-dideoxyguanosine). Not surprisingly, the enantiomers of such chiral compounds have different activities.

Carbovir and known analogues are prepared from the known γ-lactam, 2-azabicyclo[2.2.1]hept-5-en-3-one, i.e. the compound of formula



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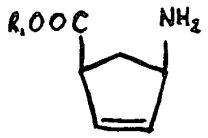
See, for example, Daluge et al, J. Org. Chem. 43(12): 2311-20 (1978). The prior art indicates that the final product, or any intermediate or starting material, may be resolved by known methods, and that a racemic mixture of the product may be enzymatically converted to chirally pure compounds. The γ-lactam can be prepared by reacting cyclopentadiene with tosyl cyanide.

R.D. Allan et al, Eur. J. Pharmacol. 122 (1986) 339-348, disclose a series of GABA analogues, resolved and unresolved, including the compound of formula II



in which R_1 is H. In particular, (+)-1R,4R-4-aminocyclopent-2-ene-1-carboxylic acid is disclosed, although its activity is much lower than that of the structurally-isomeric 1-ene.

Caamano et al, Heterocycles 27 (12):2839-41 (1988), describe an enantioselective synthesis of 2-azabicyclo[2.2.1]hept-5-en-3-one, by hydrolysis of the adduct formed by Diels-Alder addition of cyclopentadiene to the chiral dienophile (+)-10-camphorsulphonyl cyanide. The enantiomeric excess was 13%.

Sicsic et al, Tetrahedron Letters 28:1887-8 (1987), discloses that pig liver esterase is an enantioselective hydrolytic catalyst of (±)-methyl-4-cis-acetamidocyclopent-2-ene-1-carboxylate. The (+) and (-) enantiomers were obtained in 87% ee and 97% ee respectively.

Ikbal et al, Fur. J. Med. Chem. 24:415-420 (1989), discloses the chemical synthesis of racemic methyl 4-acetamido-cis-cyclopent-2-ene-1-carboxylic acid from 2-azabicyclo[2.2.1]hept-5-en-3-one, and its enzymatic resolution using pig liver esterase.

Summary of the Invention

The present invention is based on the surprising discovery of lactamases that will react with the γ-lactam of formula I to give a single enantiomer of the lactam and the corresponding ring-opened compound of formula II in an enantiomeric form. The substantially pure enantiomers of formula I wherein the enantiomeric excess is not less than or equal to 13% are novel compounds, and are excellent synthons for

a desired enantiomer of Carbovir.

Description of the Invention

It is surprising that material of biological origin will react selectively with the γ-lactam of formula I, to give the desired product in good yield. The material is described herein, for convenience, as a lactamase.

Suitable activities are those present in certain novel wild-type isolates of the genera Pseudomonas, Alcaligenes, Arthrobacter, Brevibacterium, Nocardia, Rhodococcus and Corynebacterium, whilst not being limited to isolates of these genera. Selection for these activities may be conducted in the presence of compounds containing one or more N-acyl substituents. If necessary, elevated levels of activity may be produced by growth of cells in the presence of such compounds. Particular examples of suitable activity are those produced maximally active in cells of the unique strains ENZA-20 and Rhodococcus sp ENZA-1, the latter when cultivated in a suitable medium in the presence of N-acetyl-L-phenylalanine or N-acetyl-D,L-phenylalanine.

Rhodococcus sp ENZA-1 was isolated from soil samples by enrichment culture in mineral salts medium containing N-acetyl-L-phenylalanine as the sole source of carbon and energy. The isolate has been deposited at the NCIMB in Aberdeen, on 17.10.89. The accession number is NCIMB 40213.

ENZA-20 was obtained from a sewage sample, and deposited at the NCIMB on 16.01.90. The accession number is NCIMB 40249.

Novel microorganisms have the ability to cause stereoselective formation of enantiomers of, say, 2-azabicyclo[2.2.1]hept-5-en-3-one and (-)-4-aminocyclopent-2-ene-1-carboxylic acid. The deposited microorganisms may, if desired, be subjected to conventional mutagenic/selection procedures, with a view to attaining improved effects.

The reaction of the lactam with the material having lactamase activity gives a compound of formula II which can be separated, as necessary or desired, from admixture with the unreacted lactam.

If the lactamase reaction is conducted in the presence of water, R_1 is H. Alternatively, a nucleophile may be used to introduce an alkyl group R_1 directly. For example, the nucleophile is methanol.

(-)-4-Aminocyclopent-2-ene-1-carboxylic acid of formula II is often the product of the process. If desired, racemic cis amino-acid may be converted to racemic cis/trans amino-acid which is then exterified, allowing ready separation. The, say, (+)-trans ester may be isolated.

The following Examples illustrate the invention.

Example 1

Preparation of Cells

Rhodococcus sp ENZA-1 was grown in a medium containing KH_2PO_4 (7 gl^{-1}), Na_2HPO_4 (2 gl^{-1}), $MgSO_4$ (0.4 gl^{-1}), NaCl (2 gl^{-1}), $CaCl_2.6H_2O$ (0.01 gl^{-1}), $FeCl_3.7H_2O$ (0.08 gl^{-1}), $ZnSO_4.7H_2O$ (0.0001 gl^{-1}), $(NH_4)_2SO_4$ (2 gl^{-1}) yeast extract (1 gl^{-1}) and glucose (10 gl^{-1}). The medium was adjusted to pH 7.0 with 5M NaOH and sterilised by autoclaving at 121 °C for 20 min. N-acetyl-L-phenyl-alanine at pH 7 was filter-sterilised and added to the cooled medium to give a final concentration of 10 gl^{-1}. The medium was distributed in 1 litre volumes within 5 litre shake flasks and 100 ml volumes within 500 ml shake flasks. A loopful from a slant of ENZA-1 was inoculated into 100 ml of the above medium and grown at 30 °C with shaking at 200 rpm, for 24 hours. A 5 litre shake flask was then inoculated with 50 ml of the seed culture and grown under the same conditions. The whole culture was then harvested after 48 hours growth, by centrifugation, and the cell paste was stored at -20 °C until use.

Preparation of Catalyst

Following thawing, Rhodococcus sp ENZA-1 cell paste (1.50 g) was suspended in phosphate buffer solution at pH 7 (0.1 M, 3.5 ml). The suspension of cells was then disrupted by sonication, to yield an essentially cell-free extract.

Preparation of (+)-lactam and (-)-amino-acid

The racemic lactam 2-azabicyclo[2.2.1]hept-5-en-3-one (218 mg, 2 mmol) was dissolved in phosphate buffer solution at pH 7 (0.1 M, 5.0 ml) and 0.5 ml of the cell-free extract was added. The resulting mixture was then inoculated at 30 °C with shaking for 14 days.

Isolation of the (+)-lactam

The reaction mixture prepared above was extracted with dichloromethane (3 x 25 ml), and the organic layers were dried with anhydrous $MgSO_4$. Following filtration, the organic layers were concentrated by rotary evaporation at 30°C at reduced pressure, to yield a white solid (110 mg) which was fractionated by chromatography on silica (5 g) in the presence of diethyl ether as the mobile phase, to give the (+)-lactam (97 mg, 0.9 mmol; 88% e.e.).

Derivation of the (-)-amino-acid and Isolation of the (-)-ester/amide

The aqueous layer resulting from dichloromethane extraction of the reaction mixture was acidified to pH 1 with dilute HCl (1M) and then concentrated to near dryness by rotary evaporation at 35°C and reduced pressure. The resultant oil was then refluxed with benzene (25 ml) for 1 hour in a Dean-Stark apparatus to remove water. The resulting mixture was then concentrated by rotary evaporation at 35°C and reduced pressure, to yield a brown solid which was refluxed with dry methanol (25 ml) for 5 hours. The resulting solution was then filtered and evaporated to dryness at 35°C and reduced pressure. Dry pyridine (10 ml) was added, and the solution was cooled in an ice-bath. At this point, acetic anhydride (5 ml) was added dropwise with stirring, and the mixture was allowed to warm to room temperature. Following a further 2 hours stirring, the solution was concentrated by evaporation at 35°C and reduced pressure. The resulting oil was then taken up in dichloromethane (150 ml) and washed consecutively with water (30 ml), sat. $NaHCO_3$ solution (2 x 30 ml), dilute HCl (0.1 M, 2 x 30 ml) and brine (30 ml), at which point the solution was dried over anhydrous $MgSO_4$. Subsequently, the solution was concentrated by evaporation under reduced pressure at 35°C and fractionated by chromatography on silica (10 g) in the presence of a mobile phase having the composition: $CH_2Cl_2/(CH_3)_2CO$ 80:20, to yield the (-)-ester/amide (II: X = CH_2; Y-Z = -CH=CH-; R_1 = CH_3; R_2 = Ac) (128 mg, 0.7 mmol; 81% e.e.).

Example 2

The procedure of Example 1 was repeated, except that isolate ENZA-20 was used. In cell preparation, growth in the presence of N-acetyl-L-phenylalanine was not necessary. The products of reaction with the racemic lactam were the (-)-lactam and the (+)-amino-acid. The (-)-lactam had >98% e.e. The (+)-ester/amide was isolated.

Claims

Claims for the following Contracting States : AT, BE, CH, DE, DK, FR, GB, GR, IT, LU, NL, SE

1. An enzyme having lactamase activity capable of stereospecific reaction with one of the enantiomers of 2-azabicyclo[2.2.1]hept-5-en-3-one.

2. An enzyme according to claim 1, capable of stereoselective reaction with racemic 2-azabicyclo[2.2.1]-hept-5-en-3-one, to form a mixture of an enantiomer of 2-azabicyclo[2.2.1]hept-5-en-3-one and the opposite enantiomer of 4-aminocyclopent-2-ene-1-carboxylic acid or an alkyl ester thereof.

3. A microorganism having lactamase activity as defined in claim 1 or claim 2.

4. A microorganism according to claim 3, having the characteristics of that deposited as NCIMB 40213, or a mutant thereof.

5. A microorganism according to claim 4, having the characteristics of that deposited as NCIMB 40249, or a mutant thereof.

6. A process for preparing an enantiomer of 2-azabicyclo[2.2.1]hept-5-en-3-one, which comprises reacting a mixture of enantiomers of 2-azabicyclo[2.2.1]hept-5-en-3-one with an enzyme according to claim 1 or claim 2 or a microorganism according to any of claims 3 to 5.

7. A process according to claim 6, for preparing a mixture as defined in claim 2, which is conducted in the presence of a nucleophile, wher by the alkyl ester is formed.

8. A mixture of an enantiomer of 2-azabicyclo[2.2.1]hept-5-en-3-one, at least substantially free of the other enantiomer, wherein the enantiomeric excess is not less than or equal to 13%, and the opposite enantiomer of 4-aminocyclopent-2-ene-1-carboxylic acid or an alkyl ester thereof.

9. An enantiomer of 2-azabicyclo[2.2.1]hept-5-en-3-one, at least substantially free of the other enantiomer, wherein the enantiomeric excess is not less than or equal to 13%, obtainable by the process of claim 6 or by the separation of a mixture according to claim 8.

10. An enantiomer according to claim 9, which is (+)-2-azabicyclo[2.2.1]hept-5-en-3-one, in at least 88% enantiomeric excess, obtainable by the process of claim 6 or by the separation of a mixture according to claim 8.

11. An enantiomer according to claim 9, which is (-)-2-azabicyclo[2.2.1]hept-5-en-3-one, in more than 98% enantiomeric excess, obtainable by the process of claim 6 or by the separation of a mixture according to claim 8.

Claims for the following Contracting State : ES

1. A process for preparing an enantiomer of 2-azabicyclo[2.2.1]hept-5-en-3-one, at least substantially free of the other enantiomer, which comprises reacting a mixture of the enantiomers with an enzyme having lactamase activity capable of stereospecific reaction with one of the enantiomers.

2. A process according to claim 1, wherein the enantiomer produced is (+)-2-azabicyclo[2.2.1]hept-5-en-3-one, in at least 88% enantiomeric excess.

3. A process according to claim 1, wherein the enantiomer produced is (-)-2-azabicyclo[2.2.1]hept-5-en-3-one, in more than 98% enantiomeric excess.

4. A process according to any preceding claim, wherein the enantiomer produced is in admixture with the opposite enantiomer of 4-aminocyclopent-2-ene-1-carboxylic acid or an alkyl ester thereof.

5. A process according to claim 4, which is conducted in the presence of a nucleophile, whereby the alkyl ester is formed.

6. A process according to any of claims 1 to 5, wherein the enzyme is as found in a microorganism having the characteristics of that deposited as NCIMB 40123, or a mutant thereof.

7. A process according to any of claims 1 to 5, wherein the enzyme is as found in a microorganism having the characteristics of that deposited as NCIMB 40239, or a mutant thereof.

Patentansprüche

Patentansprüche für folgende Vertragsstaaten : AT, BE, CH, DE, DK, FR, GB, GR, IT, LU, NL, SE

1. Enzym mit Lactamase-Aktivität, das zu einer stereospezifischen Reaktion mit einem der Enantiomeren von 2-Azabicyclo[2.2.1]hept-5-en-3-on imstande ist.

2. Enzym nach Anspruch 1, das zu einer stereoselektiven Reaktion mit racemischem 2-Azabicyclo[2.2.1]-hept-5-en-3-on imstande ist, um eine Mischung eines Enantiomers von 2-Azabicyclo[2.2.1]hept-5-en-3-on und dem entgegengesetzten Enantiomer von 4-Aminocyclopent-2-en-1-carbonsäure oder einem Alkylester davon zu bilden.

3. Mikroorganismus mit Lactamase-Aktivität, wie in Anspruch 1 oder Anspruch 2 definiert.

4. Mikroorganismus nach Anspruch 3, mit den kennzeichnenden Merkmalen des als NCIMB 40213 hinterlegten oder eine Mutante davon.

5. Mikroorganismus nach Anspruch 4, mit den kennzeichnenden Merkmalen des als NCIMB 40249 hinterlegten oder eine Mutante davon.

6. Verfahren zur Herstellung eines Enantiomers von 2-Azabicyclo[2.2.1]hept-5-en-3-on, welches umfaßt, daß eine Mischung von Enantiomeren von 2-Azabicyclo[2.2.1]hept-5-en-3-on mit einem Enzym nach Anspruch 1 oder Anspruch 2 oder einem Mikroorganismus nach irgendeinem der Ansprüche 3 bis 5 umgesetzt wird.

7. Verfahren nach Anspruch 6, zur Herstellung einer Mischung wie in Anspruch 2 definiert, welches in Gegenwart eines Nukleophils durchgeführt wird, wobei der Alkylester gebildet wird.

8. Mischung eines Enantiomers von 2-Azabicyclo[2.2.1]hept-5-en-3-on, das mindestens im wesentlichen frei von dem anderen Enantiomer ist, wobei der enantiomere Überschuß nicht weniger als oder gleich 13% ist, und dem entgegengesetzten Enantiomer von 4-Aminocyclopent-2-en-1-carbonsäure oder eines Alkylesters davon.

9. Enantiomer von 2-Azabicyclo[2.2.1]hept-5-en-3-on, das mindestens im wesentlichen frei von dem anderen Enantiomer ist, wobei der enantiomere Überschuß nicht weniger als oder gleich 13% ist, erhältlich durch das Verfahren nach Anspruch 6 oder durch die Trennung einer Mischung nach Anspruch 8.

10. Enantiomer nach Anspruch 9, welches (+)-2-Azabicyclo[2.2.1]hept-5-en-3-on ist, in einem mindestens 88%-igen enantiomeren Überschuß, erhältlich durch das Verfahren nach Anspruch 6 oder durch die Trennung einer Mischung nach Anspruch 8.

11. Enantiomer nach Anspruch 9, welches (-)-2-Azabicyclo[2.2.1]hept-5-en-3-on ist, in einem mehr als 98%-igen enantiomeren Überschuß, erhältlich durch das Verfahren nach Anspruch 6 oder durch die Trennung einer Mischung nach Anspruch 8.

Patentansprüche für folgenden Vertragsstaat : ES

1. Verfahren zur Herstellung eines Enantiomers von 2-Azabicyclo[2.2.1]hept-5-en-3-on, das mindestens im wesentlichen frei von dem anderen Enantiomer ist, welches umfaßt, daß eine Mischung der Enantiomere mit einem Enzym mit Lactamase-Aktivität, das zu einer stereospezifischen Reaktion mit einem der Enantiomere imstande ist, umgesetzt wird.

2. Verfahren nach Anspruch 1, worin das hergestellte Enantiomer (+)-2-Azabicyclo[2.2.1]hept-5-en-3-on ist, in einem mindestens 88%-igen enantiomeren Überschuß.

3. Verfahren nach Anspruch 1, worin das hergestellte Enantiomer (-)-2-Azabicyclo[2.2.1]hept-5-en-3-on ist, in einem mehr als 98%-igen enantiomeren Überschuß.

4. Verfahren nach irgendeinem der vorhergehenden Ansprüche, worin das hergestellte Enantiomer in Mischung mit dem entgegengesetzten Enantiomer von 4-Aminocyclopent-2-en-1-carbonsäure oder einem Alkylester davon vorliegt.

5. Verfahren nach Anspruch 4, welches in Gegenwart eines Nukleophils durchgeführt wird, wobei der Alkylester gebildet wird.

6. Verfahren nach irgendeinem der Ansprüche 1 bis 5, worin das Enzym so ist, wie es in einem Mikroorganismus mit den kennzeichnenden Merkmalen des als NCIMB 40213 hinterlegten gefunden wird, oder einer Mutante davon.

7. Verfahren nach irgendeinem der Ansprüche 1 bis 5, worin das Enzym so ist, wie es in einem Mikroorganismus mit den kennzeichnenden Merkmalen dem als NCIMB 40249 hinterlegten gefunden wird, oder einer Mutante davon.

Revendications

Revendications pour les Etats contractants suivants : AT, BE, CH, DE, DK, FR, GB, GR, IT, LU, NL, SE

1. Enzyme ayant une activité lactamase capable de réaction stéréospécifique avec l'un des énantiomères de 2-azabicyclo[2.2.1]hept-5-èn-3-one.

2. Enzyme selon la revendication 1, capable de réaction stéréosélective avec le 2-azabicyclo[2.2.1]hept-5-èn-3-one racémique, pour former un mélange d'un énantiomère de 2-azabicyclo[2.2.1]hept-5-èn-3-one et de l'énantiomère opposé d'acide 4-aminocyclopent-2-ène-1-carboxylique ou d'un ester alkylique de celui-ci.

3. Micro-organisme ayant une activité lactamase comme défini dans la revendication 1 ou la revendication 2.

4. Micro-organisme selon la revendication 3, ayant les caractéristiques de celui déposé en tant que NCIMB 40213, ou d'un mutant de celui-ci.

5. Micro-organisme selon la revendication 4, ayant les caractéristiques de celui déposé en tant que NCIMB 40249, ou d'un mutant de celui-ci.

6. Procédé de préparation d'un énantiomère de 2-azabicyclo[2.2.1]hept-5-èn-3-one, qui comprend la réaction d'un mélange d'énantiomères de 2-azabicyclo[2.2.1]hept-5-èn-3-one avec une enzyme selon la revendication 1 ou la revendication 2 ou un micro-organisme selon l'une quelconque des revendications 3 à 5.

7. Procédé selon la revendication 6, pour préparer un mélange comme défini dans la revendication 2, qui est mis en oeuvre en présence d'un nucléophile, par lequel l'ester alkylique est formé.

8. Mélange d'un énantiomère de 2-azabicyclo[2.2.1]hept-5-èn-3-one, au moins pratiquement dépourvu de l'autre énantiomère, dans lequel l'excès énantiomérique n'est pas inférieur ni égal à 13 %, et de l'énantiomère opposé d'acide 4-aminocyclopent-2-ène-1-carboxylique ou d'un ester alkylique de celui-ci.

9. Enantiomère de 2-azabicyclo[2.2.1]hept-5-èn-3-one, au moins pratiquement dépourvu de l'autre énantiomère, dans lequel l'excès énantiomérique n'est pas inférieur ni égal à 13 %, pouvant être obtenu par le procédé de la revendication 6 ou par la séparation d'un mélange selon la revendication 8.

10. Enantiomère selon la revendication 9, qui est le 2-azabicyclo[2.2.1]hept-5-èn-3-one (+), en excès énantiomérique d'au moins 88 %, pouvant être obtenu par le procédé de la revendication 6 ou par la séparation d'un mélange selon la revendication 8.

11. Enantiomère selon la revendication 9, qui est le 2-azabicyclo[2.2.1]hept-5-èn-3-one (-), en excès énantiomérique de plus de 98 %, pouvant être obtenu par le procédé de la revendication 6 ou par la séparation d'un mélange selon la revendication 8.

Revendications pour l'Etat contractant suivant : ES

1. Procédé de préparation d'un énantiomère de 2-azabicyclo[2.2.1]hept-5-èn-3-one, au moins pratiquement dépourvu de l'autre énantiomère, qui comprend la réaction d'un mélange d'énantiomères avec une enzyme ayant une activité lactamase capable de réaction stéréospécifique avec l'un des énantiomères.

2. Procédé selon la revendication 1, dans lequel l'énantiomère produit est le 2-azabicyclo[2.2.1]hept-5-èn-3-one (+), en excès énantiomérique d'au moins 88 %.

3. Procédé selon la revendication 1, dans lequel l'énantiomère produit est le 2-azabicyclo[2.2.1]hept-5-èn-3-one (-), en excès énantiomérique de plus de 98 %.

4. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'énantiomère produit est en mélange avec l'énantiomère opposé d'acide 4-aminocyclopent-2-ène-1-carboxylique ou d'un ester alkylique de celui-ci

5. Procédé selon la revendication 4, qui est mis en oeuvre en présence d'un nucléophile, dans lequel l'ester alkylique est formé.

6. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel l'enzyme est telle que découverte dans un micro-organisme ayant les caractéristiques de celui déposé en tant que NCIMB 40123, ou d'un mutant de celui-ci.

7. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel l'enzyme est telle que découverte dans un micro-organisme ayant les caractéristiques de celui déposé en tant que NCIMB 40239, ou d'un mutant de celui-ci.